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Effect of attention on multimodal cue integration

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1 Introduction

Humans gather information about their environment from multiple sensory channels. It seems that cues from separate sensory modalities (e.g. vision and haptics) are combined in a statistically optimal way according to a maximum-likelihood estimator [1]. Ernst and Banks showed that for bi-modal perceptual estimates, the weight attributed to one sensory channel changes when its relative reliability is modified by increasing the noise associated to its signal.

Because increasing the attentional load of a given sensory channel is likely to change its reliability, we assume that such modification would also alter the weight of the different cues for multimodal perceptual estimates. Here we examine this hypothesis using a dual-task paradigm.

Subjects' main-task is to estimate the size of a raised bar using vision alone, haptics alone, or both modalities combined. Their performance in the main-task condition alone is compared to the performance obtained when an additional visual 'distractor'-task is performed simultaneously to the main-task (Dual-Task Paradigm).

We found that vision-based estimates are more affected by a visual 'distractor' than the haptics-based estimates. Our findings substantiate that attention influences the weighting of the different sensory channels for multimodal perceptual estimates. That is, when attention is detracted from the visual modality, the haptic estimates are consequently weighted higher in visual-haptic size discrimination.

In further experiments, we will examine the influence of a haptic 'distractor'-task. We would expect, that a haptic 'distractor' interferes to a higher extend with the haptic primary task. The vision-based estimates in the main-task should be less affected. We will then further examine whether cue integration is still statistically optimal.

2 Methods

2.1 Stimuli

The visual stimulus for the primary-discrimination-task is a random dot stereogram that represents a raised bar (Fig.1). It is presented on a cathode ray tube (CRT). Sub-

jects view the mirror image of the visual stimulus via shutter glasses (*CrystallEyes, StereoGraphics, Inc*.) that provide binocular disparity (Fig.3).

The haptic stimulus is presented with two PHANToM force-feedback devices, one each for the index finger and thumb (Fig.2).

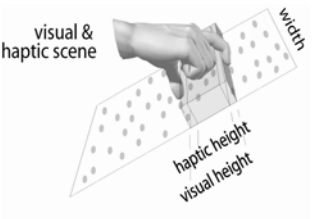


Fig. 1 Stimuli.

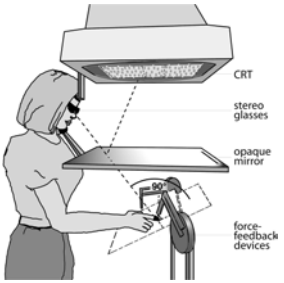


Fig. 2 Experimental Setup.

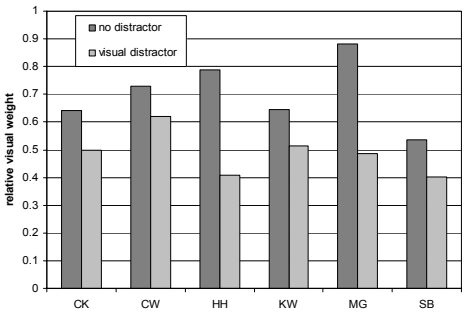
2.2 Procedure

In the primary task subjects are asked to estimate the size of a raised bar, either visually (V) or haptically (H) alone or by using information from both sensory channels simultaneously (VH). These size estimation tasks are 2-interval forced choice (2-IFC) tasks. Subjects are required to judge whether the first or the second bar was taller. From their judgments we derive psychometric functions which allow us to determine the just-noticeable differences (JNDs) and the points of subjective equality (PSE).
The secondary task consists of discriminating two sequences of letters using a same/different paradigm. The letters are presented at the midpoint of the upper surface of the bar to prevent eye movements when main-task and 'distractor'-task are conducted concurrently.

To proof our hypothesis, we determine the performance in the main-task conditions alone (V, H, VH) and compare it with the performance obtained when main- and 'distractor'-task are carried out at the simultaneously (V+VD, H+VD, VH+VD).

3 Results

Comparing the JNDs from the visual-only and the haptic-only tasks we found that vision was the more reliable modality for size discrimination given the stimuli used (Fig.3). That is, vision is expected to dominate the combined visual-haptic percept. When we introduced the secondary task the performance in the primary visual task was more affected than that of the primary haptic task. This should therefore result in a shift of dominance from the visual more towards the haptic modality in the bimodal judgements.



$$w_V = \frac{T_H^{\,2}}{T_H^{\,2} + T_V^{\,2}}$$

Fig. 3 In 4 subjects we found that the relative visual weights decrease when subjects perform main-task (single modality condition) and visual 'distractor'-task concurrently (V+VD, H+VD). The relative visual weights are calculated from the JNDs (T_H, T_V) determined in the visual-only and haptic-only conditions.

To determine the relative visual and haptic weights in the bimodal conditions (VH) we introduce a conflict between the visual and haptic size stimulus; subjects gather slightly contradictory information from both sensory channels. In this condition, the visual height is set at 51.0 mm and the haptic height at 59.0 mm and vice versa (counterbalanced conflict of ±8 mm). Such a conflict is necessary for determining the relative contributions (weights) of the two modalities to the final perceptual estimate. Using one subject we confirmed that vision dominates the visual-haptic percept when no 'distractor'-task was performed (Fig.4). That is, in both conflict situations we found that the point of subjective equality (PSE) is clearly shifted towards the actual visual input (VH). When performing a visual 'distractor'-task alongside (VH+VD), as predicted the PSEs are shifted more towards the haptic modality (Fig.4) indicating that the relative visual weights decreased.
The change in weight is best illustrated by the change in slope in the two functions of Figure 4. The visual weights without 'distractor'-task correspond to: 0.59; the visual weights with 'distractor'-task correspond to: 0.42.

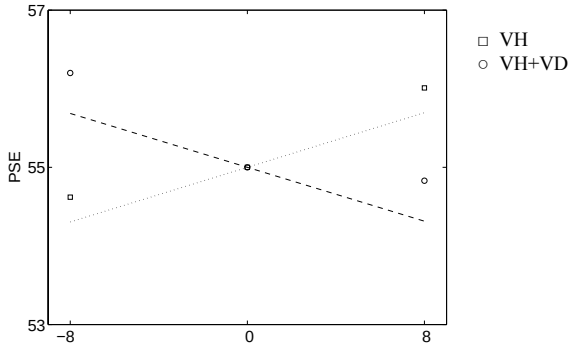


Fig. 4 Data from one subject in the size estimation task with visual and haptic information available with visual 'distractor'-task (VH+VD) and without (VH). In the cross-modal modality alone, i.e. with no 'distractor'-task (VH), the point of subjective equality is shifted towards the actual visual input; the visual-haptic estimate is dominated by the visual modality. When subjects perform a visual 'distractor'-task simultaneously the reverse effect is obtained, the haptic modality contributes to a higher extend to the unified percept.

4 Conclusions

These findings substantiate our hypothesis that attention affects the weighting of the different cues for a multimodal perceptual estimate. Increasing the load of a given sensory channel seems to results in a loss of the extent to which this modality contributes to the unified percept.

References

1. Ernst, M.O. and Banks, M.: Humans integrate visual and haptic information in a statistically optimal fashion. Nature, 415, 429-433 (2002)

Acknowledgements

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